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Autor: Dr. Götz Zeddies

Abteilung Makroökonomik

Götz.Zeddies@iwh-halle.de

Tel.: (0345) 77 53-854

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Hausanschrift: Kleine Märkerstraße 8, 06108 Halle (Saale)
Postanschrift: Postfach 11 03 61, 06017 Halle (Saale)
Telefon: (0345) 77 53-60
Telefax: (0345) 77 53-8 20
Internetadresse: http://www.iwh-halle.de

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Abstract

The last decades were characterized by large increases in world trade, not only in absolute terms, but also in relation to world GDP. This was in large parts caused by increasing exchanges of parts and components between countries as a consequence of international fragmentation of production. Apparently, greater competition especially from the Newly Industrializing and Post-Communist Economies prompted firms in 'high-wage' countries to exploit international factor price differences in order to increase their international competitiveness. However, theory predicts that, beside factor price differences, vertical disintegration of production should be driven by a multitude of additional factors. Against this background, the present paper reveals empirical evidence on parts and components trade as an indicator for international fragmentation of production in the European Union. On the basis of a panel data approach, the main explanatory factors for international fragmentation of production are determined. The results show that, although their influence can not be neglected, factor price differences are only one out of many causes for shifting production to or sourcing components from foreign countries.

Keywords: Economic Integration, International Fragmentation of Production

JEL classification: F14, F23, L23

Determinants of International Fragmentation of Production in the European Union

Zusammenfassung

Die zurückliegenden Jahrzehnte waren weltweit durch eine erhebliche Ausweitung der internationalen Handelsströme, nicht nur absolut, sondern auch in Relation zum Welt-BIP, gekennzeichnet. Dies ist zu einem Großteil auf den zunehmenden bilateralen Handel mit Vor- und Zwischenprodukten als Folge der internationalen Fragmentierung der Produktion zurückzuführen. Offensichtlich hat der im Laufe der Zeit zunehmende internationale Wettbewerbsdruck, insbesondere seitens der südostasiatischen und der mittel- und osteuropäischen Länder, die Unternehmen in Hochlohnländern veranlasst, internationale Unterschiede in den Faktorpreisen, vor allem in den Arbeitskosten, zur Steigerung ihrer preislichen Wettbewerbsfähigkeit auszunutzen. Allerdings wird die Verlagerung von Teilelementen der Wertschöpfungsketten ins Ausland aus theoretischer Sicht, neben Faktorpreisunterschieden, von einer Vielzahl weiterer Faktoren bestimmt. Vor diesem Hintergrund veranschaulicht der vorliegende Artikel auf der Basis bilateraler Daten zum Außenhandel mit Vor- und Zwischenprodukten das Ausmaß der internationalen Fragmentierung der Produktion in der Europäischen Union. Zudem werden im Rahmen einer Paneldaten-Analyse die wesentlichen erklärenden Größen der vertikalen Aufspaltung von Wertschöpfungsketten bestimmt. Die Ergebnisse zeigen, dass internationale Unterschiede in den Arbeitskosten zwar ein wesentlicher, aber dennoch nur ein erklärender Faktor unter vielen sind.

Schlüsselwörter: Internationaler Handel, Europäische Integration, Fragmentierung der Produktion

JEL-Codes: F14, F23, L23

Determinants of International Fragmentation of Production in the European Union

1 Introduction

During the last decades, international trade flows increased tremendously all over the world, not only in absolute but also in relative terms, e.g. in relation to world GDP. But the potentials of traditional theoretical approaches for explaining this phenomenon are limited (Krugman 1995). This is for instance the case for reductions in transport costs and tariffs in the context of several GATT agreements. Although their influence should not be disregarded, they can hardly explain the growth in world trade (see e.g. Yi (2003)). Another reason for the growing shares of trade in GDP all over the world might be seen in increasing similarities of countries with respect to (economic) sizes, since these have a positive influence on the exchange of varieties between them (Helpman 1987). But this second artifact is too, like many others, insufficient for explaining the increase in world trade in the last decades. The shortcoming of traditional trade models is probably the fact that they do not incorporate the changing nature of international trade which could be observed during the last years, namely the increasing exchange of parts and components as a consequence of international 'fragmentation' of production.

Apparently, trade liberalization did not just affect trade flows between countries in a direct way by stimulating the exchange of final goods through reduced tariffs. But through increasing competition in the face of globalization, primarily producers in highly developed countries were seeking to reduce production costs in order to increase their competitiveness. Beside other strategies, this can be achieved by splitting up vertically integrated production processes and by relocating different parts of production chains to different regions or countries in order to exploit factor price differences between them (Feenstra 1998). Trade in intermediate goods or parts and components between countries is often used as a suitable indicator for this phenomenon. During the past twenty years, this kind of trade has grown faster than total trade and in the meantime reaches a share of more than 30 percent in total transport and machinery imports in OECD countries (Yeats 2001). The causes for such a fragmentation of production could on the one hand be based upon different requirements in factor intensities, suggesting that more labor-intensive fragments are located in labor-abundant, lower wage regions/countries and more capital-intensive fragments in more capital-abundant regions/countries (endowment differences in the Heckscher-Ohlin style). On the other hand, different fragments might require different labor skills, implying that some regions'/countries' labor skills

are more appropriate to one fragment and other regions'/countries' labor skills are more suited with respect to another fragment of the production process (Ricardian productivity differences).

The phenomenon of the tremendous increases in trade with parts and components entered into the literature under the labels 'slicing up the value chain' (Krugman 1995), outsourcing (Feenstra and Hanson 1996), disintegration of production (Feenstra 1998), intra-product specialization (Arndt 1997), vertical specialization (Balassa 1967) or, as already mentioned, fragmentation of production (Deardorff 1998, Jones and Kierzkowski 1997). According to Hummels et al. (2001), international fragmentation of production occurs when: (1) a good is produced in at least two sequential stages, (2) two or more countries provide value-added during the production of the good and (3) at least one country must use imported inputs in its stage of the production process, and some of the resulting output must be exported. Thus, fragmentation of production boosts countries' international trade in two ways: Firstly by increasing imports of intermediate goods and, secondly, by exports of final goods or processed parts and components which incorporate the formerly imported intermediates. The more sequential stages in different countries the production process of a good contains, the more international borders will be crossed during the production and the more international trade will be induced.

Whereas earlier the process of fragmentation of production took place within countries, the reduction of trade barriers and costs of coordination simplified the establishment of international or even global production networks. Especially within East Asia and between the U.S. and Mexico the shares of parts and components in total trade grew considerably since the 1960s. In Europe, trade structure between Central and Eastern European countries (CEECs) and the old EU-Member States changed during the 1990s in a similar way: the shares of capital goods and parts in total trade between several Eastern and Western European countries increased at the expense of trade in final goods. Furthermore, an increasing correlation between imports and exports of these countries could be observed, suggesting that fragmentation of production plays effectively an important role (Kaminski and Ng 2001). But since the causes for this development might be manifold and can probably not only be assigned to the opening up of Eastern European markets with considerably lower production costs, deeper analysis is necessary.

Although the phenomenon of international fragmentation of production is not really new, it gained attention especially by the integration of the Newly Industrializing countries in East Asia and the former communist countries of Eastern Europe into the international division of labor. But empirical work on the basis of international trade data is so far mostly based on statistical analyses of trade flows, mainly focused on East Asia (see e.g. Ando 2006, Athukorala 2006, Yi 2003, Kaminski and Ng 2001). Another strand of the literature focuses on the implications of fragmentation of production for the labor markets (see e.g. Helg and Tajoli 2005, Falk and Wolfmayer 2005). The few

studies dealing with the causes of the phenomenon, which, as already mentioned, can be manifold, are in large part either based on input-output analysis for single countries or microeconomically funded using intra-firm data (e.g. Borga and Zeile 2004, De Simone 2004). Empirical analyses based on trade data for European countries are limited to outward processing trade (OPT) (e.g. Baldone et al. 2001, Egger and Egger 2005). Baldone et al. found that outward processing trade between four Western and five Eastern European countries is determined mainly by labor cost differences and geographical and cultural proximity. Egger and Egger also find that cost differences and service link costs are essential determinants for outward processing trade between Eastern and Western European countries. But since both analyses focus on outward processing trade, the whole extent of international fragmentation of production is underestimated. Additionally, data for OPT are available only until 1999. So the recently observed tendency that firms apparently withdraw delocalization of production is not covered. Moreover, as almost all other empirical studies on this issue, the absolute levels of outward processing trade between countries are explained, but not their share in total trade. Thereby, these empirical models are kind of gravity approaches. In these models, problems might arise from the fact that many of the explanatory variables do influence trade in general and thus intermediate goods and final goods trade in the same way. Thus, if total bilateral trade in parts and components acts as dependent variable, one of the core assumptions of fragmentation theory presuming that the influence of these explanatory variables on intermediate goods trade is even stronger than on trade in final goods is neglected. Hence, these models fail to explain trade structure and the changing nature of trade.

In the present paper, extent and determinants of international fragmentation of production in the European Union shall be identified. Although differences in production costs, especially labor costs, between countries are supposed to have fostered fragmentation of production during the last decades, it is assumed that factor price differences are a necessary, but not the only sufficient condition for international fragmentation of production. In the following section 2 the theoretical background on fragmentation of production and different explanatory factors will be reviewed. Afterwards, in chapter 3 empirical evidence for the extent and the regional orientation of parts and components trade between selected European countries is presented. In section 4, a model is applied to test for the different theoretical hypotheses in order to identify the main determinants of disintegration of production processes in the European Union. Finally, section 5 closes with some concluding remarks.

2 Theoretical Background

The phenomenon of international fragmentation of production can occur in three different kinds: (1) outward processing trade (OPT), (2) vertical specialization, and (3) outsourcing. All of these forms can involve direct control of the foreign subcontractor if they are accompanied by foreign direct investment. Outward processing trade incorporates vertically linked production systems where production phases of a principal's manufacturing activities are shifted abroad and products are temporarily exported for processing and afterwards re-imported (back-and-forth transactions, see e.g. Ando 2006). Since OPT concerns goods whose production process can be split up into different phases, it is a subset of vertical specialization. But beside OPT, the latter can also be realized by market relationships without any participation of the principal company in the subcontractor's business activities. Outsourcing differs from vertical specialization and OPT by the fact that intermediate goods cross international borders only once. Only if the final goods manufactured with imported intermediates are sold domestically, outsourcing is at hand, but if the final goods are at least partly exported this transaction enters the domain of vertical specialization (Fabbris and Malanchini 2000). These new kind of trade patterns of countries in many regions in the world emerging from disintegration of production challenged once more traditional trade theories. Typical North-South inter-industry trade diminished more and more in favor of intra-industry trade, even between countries for which traditional theory of comparative advantages would predict persistent inter-industry trade caused either by differences in resource endowments or productivities. For the great majority of countries, this increase in intra-industry trade was largely due to augmenting international exchanges of parts and components (Ando 2006).

According to theory, vertical disintegration of production processes across different countries should be driven by comparative advantages either in the Ricardian sense, i.e. by productivity differences, or in the Heckscher-Ohlin style, i.e. by endowment based factor price differences (Jones and Kierzkowski 2001). As a result, productivity or factor endowment differences should motivate fragmentation of production between countries. But, as stressed by some authors, in the case of international fragmentation of production the orthodox framework of comparative advantages has to be regarded more different than in the standard final goods case. For a final good, comparative advantages can be derived as long as the good fully incorporates country specific relative endowment and/or productivity characteristics. But in the case of fragmentation of production, different country specific advantages are combined. This could for instance mean that a country exporting a final good does not necessarily need to have comparative advantages in each stage of the production process or, put differently, that a country, even if it seems to have a comparative advantage in the production of a final good originating from a certain industrial sector, might have comparative disadvantages in single stages of the production process. In such a case, splitting-up the value chain allows for a more

in-depth specialization within single industries. Subsequently, trade flows can originate in absolute cost advantages and the specific combination of production stages located in different countries (De Simone 2004). But on the other hand, splitting up the value chain is not costless. Production in different locations or by different firms needs to be coordinated and is connected for instance with costs of transportation, communication or insurance. Thus, there is a trade-off between these so called 'service link costs' and costs of production blocks, since fragmentation can lower total marginal costs of production only at the expense of higher service link requirements (Jones, Kierzkowski and Lurong 2005). And service link costs are supposed to be unevenly higher if fragmentation of production doesn't take place within a single country, but on an international level and coordination has to be arranged across borders.

Although not falling directly in the category of service link costs, barriers to trade, such as tariffs and non-tariff barriers to trade, are an essential determinant of fragmentation of production (Deardorff 1998). A reduction of tariffs and/or non-tariff barriers to trade would, in the presence of international fragmentation of production, boost international trade in parts and components considerably more than trade in final goods, since in the former case the production process of a good is connected with several border crossings. In case of a tariff reduction of one percentage point, production costs of a good produced in N sequential stages with each stage in a different country would reduce by more than one percentage point, compared to a 1 percent reduction in case of a regular good that is completely produced in one country and afterwards exported (Yi 2003). Hence, the level of tariffs and/or non-tariff barriers to trade is essential for the degree of fragmentation of production. The same holds for transportation costs, which might be of higher relevance for trade in parts and components than for trade in final goods due to the above mentioned fact that in the first case the number of shipments rises with the number of sequential production stages. Consequently, international fragmentation of production should be the higher, the lower transportation costs between countries are (Golub et al. 2007). Thus, the decline in transportation costs during the last decades should have promoted delocalization of production (Jones 2000). Basically, transportation costs are the higher, the greater the distance between countries is. But additionally, the quality of infrastructure should have a significant influence on transportation costs (Bougheas et al. 1999).

Beside distance and quality of transportation networks, further important elements of service links are (tele-)communication technologies. As already stated, it can be assumed that domestic service links are cheaper than those required for connecting production blocks located in different countries. And not only transportation costs and tariffs, but also the costs of other services, as for instance international telephone calls or insurance services, declined due to greater competition, whereas their availability increased in course of deregulation. This contributed to the 'death of distance' and made coordination of production blocks around the world feasible (Jones and Kierzkowski 2001). In the context of service links, imperfect competition and increasing returns to scale are

relevant. Under these assumptions, higher output levels would lower unit costs in international production networks since service links involve chiefly fixed costs and output increases in different production blocks of a firm would only marginally increase total coordination costs (Jones and Kierzkowski 2001). Subsequently, from a microeconomic perspective, fragmentation of production becomes more cost-efficient, the larger market potentials and firm sizes are. From a macroeconomic perspective, models in the spirit of the new trade theories emphasize that comparative advantages do not play a dominant role for trade flows between developed countries. Similarly to the final goods case, it is rather imperfect competition and productivity gains of intermediate goods producers stimulating intra-industry trade in homogenous or differentiated intermediate goods. Therefore, in the presence of monopolistic competition in intermediate goods markets, the size of economies becomes a crucial determinant of international fragmentation of production and trade in differentiated intermediate inputs between countries (Ethier 1982).

In the context of market sizes, another aspect is of importance. Since fragmentation of production is always connected with the search for potential partners abroad, firms should prefer to concentrate their search on thicker markets, because it is more likely to find a business partner with the appropriate skills for producing components or services for the final producers needs in larger countries. Inversely, input producers in large markets serving more costumers probably fare better than competitors from smaller countries (Grossman and Helpman 2005). In the presence of low transportation costs, regional concentrations of intermediate input producers may result in agglomeration effects or network externalities, for instance by spillover effects, the concentration of human capital or the proximity to research facilities in core regions (Krugman 1991). Moreover, an augmenting number of firms in a country does not only increase the likelihood for foreign firms to find appropriate suppliers for intermediate inputs in the respective country, but also the countries potential for outsourcing. Thus, international fragmentation of production and trade in parts and components between countries should increase with the number of firms, be it in the exporting, the importing or in both countries. Of course, the costs and likelihood of finding a suitable partner in foreign markets will additionally be affected by the technology for searching. And these costs will again depend on the quality of a countries (tele-)communication-infrastructure.

Further aspects influencing a firms decision for slicing up the value chain internationally can be political conditions, either the political frameworks in potential target countries or the political conditions between countries involved in the process of disintegration of production. Beside others, the risk of political instabilities, uncertainties about political measures, legal uncertainty, exchange risks or imminent trade restrictions should lower the willingness of firms to relocate stages of the production chain to other countries. Subsequently, parts and components trade should be higher between countries belonging to areas of regional integration not only due to the reduction of trade barriers between member countries, but also because trade with other member countries might be viewed

as being somehow more secure or less likely to encounter disruptions or restrictions than trade with non-member countries (Yeats 2001).

Finally, factor price differences have to be reconsidered. As stated above, differences in factor prices originating from differences in factor endowments or productivities should motivate the relocation of different parts of the production chain to different locations. But, as already mentioned, fragmentation of production will only take place if cost savings from producing fragments in countries with different factor prices are large enough to offset the needs for additional resources. Beside the above described barriers or costs originating from fragmentation of production, further aspects concerning factor endowments or productivities have to be considered. A necessary precondition for a firm to relocate parts of the production process is the ability of potential partners abroad to manufacture components or services according to its specific needs. Whereas on the one hand firms seek to exploit different factor prices between countries, on the other hand factor endowment or productivity differences should not exceed a certain degree, since this would require high investments in the foreign production network or local human resources in order to customize the externally procured inputs to the needs of the principal firm. Thus, although fragmentation of production should on the one hand be encouraged by factor price differences, it should on the other hand simultaneously be limited by diverging labor force qualifications and states of production technologies between countries (Grossman and Helpman 2005). Not only labor skills and education, but also technological capabilities and the willingness of a country to overcome potential deficiencies in these areas, e.g. by investments in research and development or education, are prerequisites to integrate in the process of production sharing with high-wage countries (Yeats 2001). Hence, it can be assumed that international differences in research and development expenditures as an indicator for human capital endowments or technological capabilities of countries will have a negative influence on fragmentation of production.

On the basis of these theoretical fundamentals, an empirical analysis of the determinants of fragmentation of production between selected European countries will be conducted. But first of all, in the following section, empirical evidence on trade in parts and components as an indicator for fragmentation of production between European countries will be regarded.

3 Empirical Evidence

The analysis of trade in parts and components was for a long time impeded by a lack of statistical data, since international trade data did not distinguish between components and assembled products. But already with revision 2 of the Standard International Trade Classification (SITC) system and especially with revision 3 an identification of parts and components trade became much easier, at least in the two main product groups (SITC 7 and 8). These groups (machinery and transport equipment (SITC 7) and miscellaneous manufactured articles (SITC 8)) account for about 53 percent of total trade in goods for the selected European countries and for around 70 percent of trade in total manufacturing. At least for the remaining manufactured products not contained in SITC groups 7 and 8 the shares of parts and components trade in total trade with these products can be assumed to be quite similar (Yeats 2001). For the SITC groups 7 and 8, 225 out of 1217 subgroups at the 5-digit-level (168 in SITC 7 and 57 in SITC 8) are identified as parts and components (see e.g. Athukorala 2006).[1] In the subsequent empirical analysis, bilateral trade flows between the following 17 European countries were investigated with respect to parts and components trade: Austria, Bulgaria, Belgium, the Czech Republic, France, Germany, Great Britain, Hungary, Ireland, Italy, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia and Spain. On the one hand, the selection of countries was based on data availability. On the other hand, the country sample contains Western European 'high-wage' countries, Southern European countries, which (partly) experienced sharp increases in trade and FDI flows with Western European countries in the 1980s (Buch et al. 2001), and finally Eastern European economies as important recipients of foreign direct investment flows from Western Europe since the 1990s. Of course, as mentioned in chapter 2, fragmentation of production must not necessarily be connected with foreign direct investment. But nevertheless, if only parts of fragmentation of production go hand in hand with direct control of foreign firms by the principal companies, FDI flows could act as a robust indicator for the establishment of international production networks.

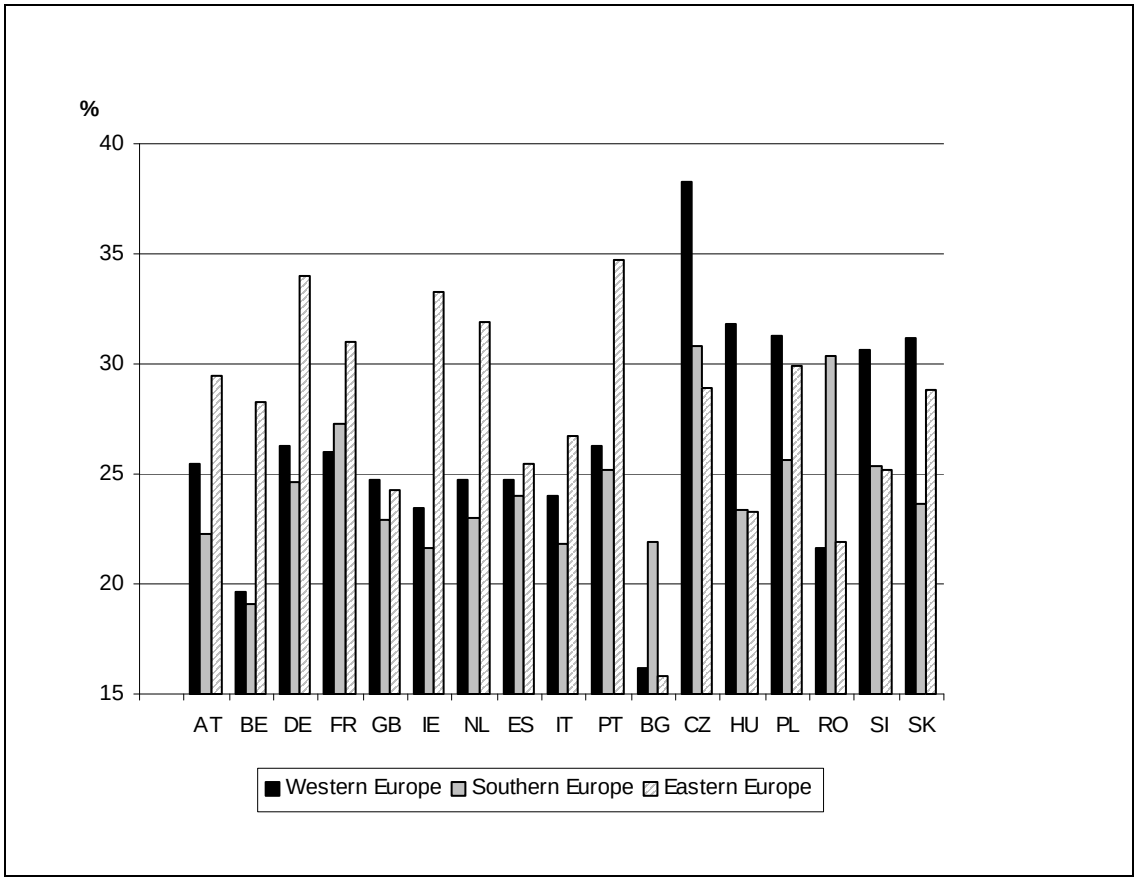
Figure 1 illustrates for each country the shares of parts and components exports and imports in total trade in SITC groups 7 and 8 with different country groups in 2005[2]. For all of the Western European countries, the share of parts and components in 2005 was highest in trade with the Eastern European countries and, with the exception of France, lowest in trade with the Southern European countries. Interestingly, with the exception of France, for each of the Western European countries intermediate goods trades' share in total trade is higher in trade with the remaining Western European countries than with

1 A list of the SITC groups defined as parts and components on the 5-digit-level can be obtained on request.

2 Parts and components exports and imports in SITC groups 7 and 8 divided by total SITC 7 and 8 exports to and imports from the respective country group.

the Southern European countries. For the Southern European countries Italy, Portugal and Spain parts and components' share in total trade is also highest with the Eastern European countries and lowest within the group of Southern European countries. As far as the Eastern European countries are concerned, the share of parts and components is highest in trade with the Western European countries, with Bulgaria and Romania being the only exceptions. For the latter, the high shares of parts and components trade with the group of the Southern European countries is probably caused by substantial trade volumes in the textiles and clothing sector with Italy in terms of outward processing trade. Overall, the share of parts and components trade in total trade is highest for the Eastern European countries, again with the exception of Bulgaria and Romania. In first sight, these facts suggest that the prevalent hypothesis implying either outsourcing from Western to Eastern European countries or back-and-forth trade between Western and Eastern European countries holds. But this has to be considered in more detail.

Figure 1:
Share of Parts and Components Trade in Total Trade by Country Groups in 2005.



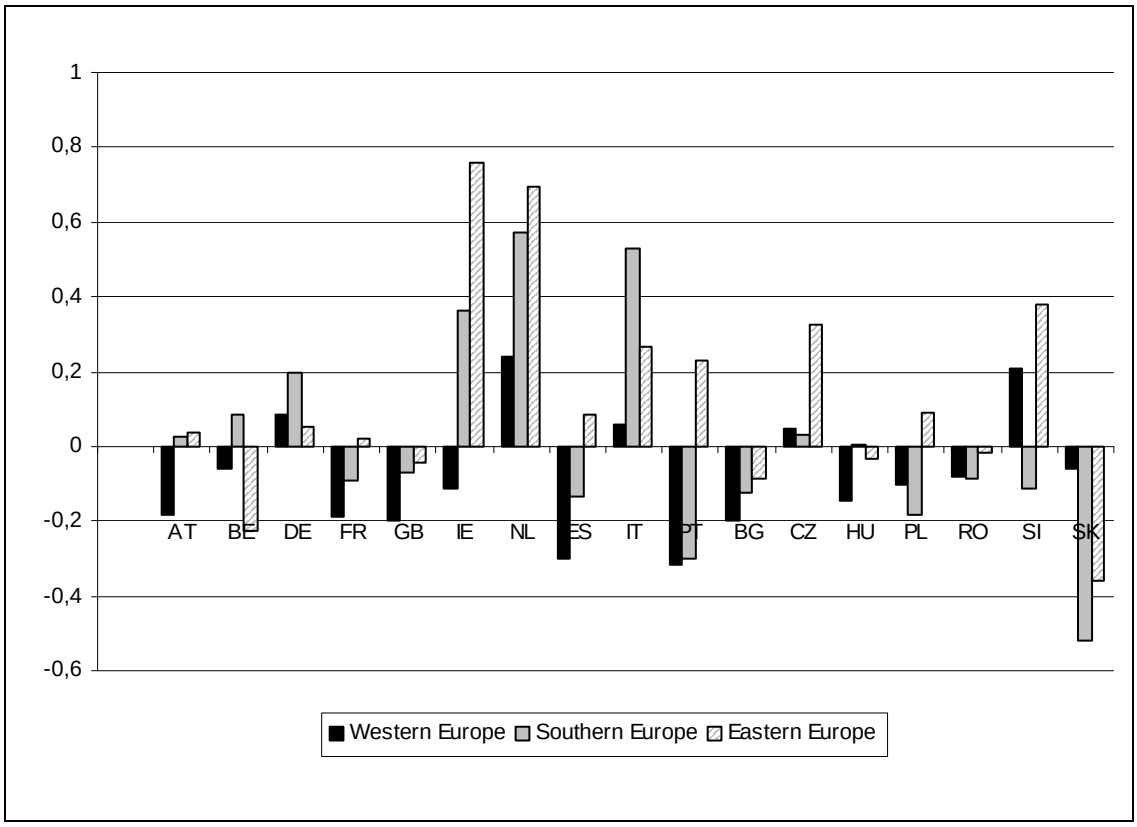
Source: EUROSTAT

Figure 2 illustrates the relative trade balances in parts and components trade of single countries with different country groups, calculated by parts and components trade bal-

ance in relation to total parts and components trade. The results shown in Figure 2 indicate that for many countries trade in parts and components is nearly balanced. As for Western Europe, Belgium is the only country with a significant deficit in parts and components trade with the Eastern European countries. But on the other hand, Ireland and the Netherlands as well as the Southern European countries have considerable surpluses in intermediate goods trade with the former communist countries. For Austria, France, and the United Kingdom, deficits in parts and components trade occur mainly with the remaining Western, but not with the Eastern European countries. Consequently, parts and components trade of the Eastern European countries is too nearly balanced vis-à-vis the Western European trading partners, as only Bulgaria, Hungary and Slovenia show greater imbalances. Beside intermediate goods trade of Ireland and the Netherlands with the Eastern and Southern European countries, considerable trade imbalances in the exchange of parts and components do only occur within the group of the Southern European countries, between Italy as well as Portugal and Eastern Europe and Portugal and the other Southern European countries. Similarly, for the Eastern European countries significant imbalances in parts and components trade occur mainly within the country group, as is the case for the Czech Republic, Slovenia and Slovakia. The high deficits in parts and components trade of Slovakia with the Southern European countries emerge from high imports especially of parts for aircraft, automobiles and electrical and electronic equipment, primarily from Italy, but also from Spain.

Albeit slight differences from country to country, Figure 2 shows that overall, the regarded ‘high-wage’ Western European countries are no net-importers of parts and components from Eastern and Southern Europe. The mostly balanced or at least not highly imbalanced accounts in intermediate goods trade for most of the regarded Western European countries with the groups of the Eastern as well as the Southern European trading partners (and vice versa) presented in Figure 2 shed light on trade patterns between these countries. Since imbalances in intermediate goods trade are, with the exception of Ireland and the Netherlands, mostly limited, trade between these countries might either take place in the form of back and forth transactions as in the case of outward processing trade, where intermediate goods are temporarily exported for further processing abroad and afterwards re-imported. Alternatively, the structure of parts and components trade could result from vertical specialization in parts and components production, suggesting that according to factor endowments Western European countries specialize on higher quality and more capital intensive parts and components, whereas for instance the Eastern European countries focus on lower quality and more labor intensive intermediate goods. A closer analysis of the determinants of trade patterns observed between the considered countries follows in section 4.

Figure 2:
Parts and Components Trade Balance in Relation to Total Parts and Components Trade by Country Groups in 2005.



Source: EUROSTAT

4 Empirical Analysis

4.1 Dependent and Explanatory Variables

Subsequently, an econometric panel data approach is applied to determine the influence of different explanatory factors on parts and components trade between countries. Therefore, bilateral datasets for 136 country pairs (i and j) and three different years with parts and components trade as the dependent variable enter into the sample. Parts and components trade between countries i and j includes exports from country i to country j as well as exports from country j to country i. Data were drawn from the EUROSTAT database for the years 1999, 2002 and 2005.

In terms of the independent variables, theory predicts that country sizes play a crucial role. In the context of new trade theories, the presence of monopolistic competition and economies of scale should motivate intra-industry trade in parts and components between countries. Therefore, theoretical models postulate that gross domestic products of trading partner countries should have a positive influence on bilateral exchanges of intermediate goods. However, in the present analysis instead of gross domestic products of trading partner countries i and j average turnover per company in the manufacturing industries corresponding to SITC groups 7 and 8 was calculated to incorporate economies of scale on the microeconomic level (EoS_{ij}). This indicator is more precise than average GDPs, since the existence of economies of scale does strictly speaking not depend on market, but on firm sizes. For instance, in the Eastern European countries firm sizes could still be comparatively large as a result of historical reasons despite relatively small domestic markets. Due to the theoretical suggestion that coordination costs between different elements of production networks are almost independent from output, increasing firm sizes should lower unit costs in production networks and thereby foster fragmentation of production and bilateral trade in intermediate goods. Like for all other sector specific explanatory variables, the data for EoS_{ij} were drawn from the EUROSTAT database in those NACE-categories corresponding to SITC-groups 7 and 8.

For capturing the negative influence of trading partner countries' market thickness on the costs of searching potential partners in foreign markets and thus on total costs of fragmentation of production, the number of firms abroad shall be taken into account. But not only the number of establishments in trading partner countries j, but also in the home country i should stimulate fragmentation of production and bilateral parts and components trade, since the potential for shifting production to or sourcing components from foreign countries rises with the number of domestic firms. Hence, the variable NOF_{ij} represents the total number of firms in both trading partner countries i and j. The higher the number of establishments, be it in country i, in country j or in both countries, the higher bilateral parts and components trade should be. Of course, the number of firms variable could seem to be contradictory to the economies of scale variable, since

an increasing number of firms would ceteris paribus lower the potential for firm specific scale externalities. But in contrast, in the presence of agglomeration effects additional external economies of scale or regional network externalities would occur and could compensate diminishing firm specific scale externalities.

Whereas firm sizes affect service link costs per unit of output, the absolute level of service link costs between different production sites depend inter alia on transportation costs. But these are not only determined by total distances between different locations, but also by the quality of infrastructure. To reflect transportation costs, distances (by road) between the capital cities of countries i and j are incorporated in the variable $DIST_{ij}$, which is expected to have a negative influence on the exchange of parts and components between countries. The quality of the road network is embodied in the variable $HIGHWAYS_{ij}$, which stands for the share of highways in total distance between the capital cities of countries i and j. The higher the share of highways in total road network between the capitals of countries, the more parts and components trade should take place between them, since delivery times, which are crucial in production networks, are reduced drastically.

As pointed out earlier, service link costs depend furthermore on the availability and prices of banking, insurance and telecommunication services in the respective countries. Strictly speaking, an aggregate service variable should be created incorporating all kind of services relevant to the issue. But this would raise new problems, for instance with respect to weighting single elements of the indicator. Instead, beside transportation costs and quality of infrastructure as two elements of service link costs, the numbers of internet hosts per ten-thousand inhabitants in both trading partner countries will be added as a third indicator for service link costs representing the countries' telecommunication infrastructure. But of course, not the average number of internet hosts per ten-thousand inhabitants in the respective countries is relevant, but only the lower one of the values in countries i and j, because the lower value represents the restrictive factor. Therefore, the variable $minWEBHOSTS_{ij}$ comprises the minimum number of internet hosts per ten-thousand inhabitants of trading partner countries i and j. A positive impact on fragmentation of production is expected.

Finally, it can be assumed that, beside the level of service link costs, fragmentation of production depends on other costs and potential risks associated with the relocation of parts of the production chain to foreign countries, like for instance tariffs and non-tariff barriers to trade or political risks and uncertainties. But since only European countries are considered, these costs should be presumably low. First of all, tarifary barriers to trade also in the Eastern European countries were nearly abolished until 1999, the first year in the sample, by the European Agreements which came into force until 1996. Second, the fact that EU accession of all Eastern European countries was agreed on in 1999 already, only the perspective of EU accession and the institutional reforms carried out in the face of EU accession should have considerably lowered political uncertainties and

risks and should have promoted the relocation of parts of production chains to these countries from Western Europe. Therefore, the introduction of a variable capturing political risks and/or barriers to trade was abandoned.

Differences in factor endowments or productivities and resulting factor price differences between countries are often said to be the most prominent factors fostering fragmentation of production. Therefore, differences in labor productivity between countries i and j (absolute value) in the NACE-categories corresponding to SITC 7 and 8 product groups were calculated using value added per employee as a proxy for capital-labor ratios and/or productivity differences ($CLDIFF_{ij}$). According to traditional trade theories, this variable should have a positive prefix. But, as stated above, traditional trade theories focussing on comparative advantages might be shortcoming in the context of fragmentation of production, because a country might export parts of a final good even if it does not have comparative advantages in the relevant industry as a whole, but only in parts of the production process of goods emerging from that sector. Hence, the variable $LCDIFF_{ij}$, which embodies absolute labor cost differences per employee between countries i and j in the NACE-categories corresponding to SITC groups 7 and 8, is introduced. These were calculated by the sum of wages, salaries and social security contributions divided by the total number of employees (full time equivalents) in the respective NACE-category. Labor cost differences between countries are expected to have a positive influence on bilateral trade in intermediate goods. But, as pointed out earlier, shifting parts of the production chain from high-wage to lower-wage countries is on the other hand limited by the capabilities of foreign affiliates or partners to manufacture intermediates according to the needs of the final producers. Whilst on the one hand, the more heterogeneous countries are in economic terms, the higher factor price differences between them, but the greater the differences in their technological and/or human resource capacities. It is assumed that countries' technological capabilities and human capital endowment depend on research and development expenditures and that high differences in R&D-spending reduce the extent of fragmentation of production between them. The variable $HTRDIFF_{ij}$ covers the differences in technological capabilities and human resource endowment differences measured by differences in entrepreneurial R&D-expenditures in relation to turnover in the manufacturing sector between countries i and j and should have a negative impact on bilateral parts and components trade. Of course, diverging research and development expenditures could also be interpreted in a similar way as $CLDIFF_{ij}$, because they can enlarge factor productivity as well as endowment differences between countries against the background of the neo factor proportions theorem. Therefore, the influence on parts and components trade could also be positive.

Before the empirical analysis is carried out, the dependent variable should be reconsidered. As mentioned earlier, fragmentation of production between countries should be measured by bilateral exchanges of parts and components. Problems might arise from the circumstance that parts and components trade is only a share in total trade. Since

many of the explanatory variables do not just influence trade in intermediate products, but total trade in the same way, the results of the econometric analysis could be misleading and falsely interpreted if the absolute level of parts and components trade between countries would be chosen as dependent variable. For instance, on the basis of different theoretical approaches one could argue that reductions in service link and transportation costs or larger firm sizes should not only promote trade in parts and components, but trade in general (Jones et al. 2005). But the logic of fragmentation theory says that most of the explanatory variables should have a stronger impact on trade in intermediate products than on trade in final goods. Consequently, not the total volume in parts and components trade between countries, but its share in total trade should be chosen as dependent variable. So, the variable $PCSHARE_{ij}$ stands for parts and components trade in SITC groups 7 and 8 divided by total trade in the respective product groups between countries i and j (exports from country i to country j as well as exports from country j to country i).

4.2 Model and Econometric Implementation

On the basis of the precedent considerations, the following econometric panel data model can be derived:

$$PCSHARE_{ijt} = \alpha + \beta_n X_{ijt} + \gamma_m Y_{ijt} + \mu_{ijt} \quad (1)$$

where $PCSHARE_{ijt}$ stands for the relative share of parts and components trade in SITC groups 7 and 8 between countries i and j in period t, X_{ijt} is the set of n industry-specific explanatory variables, Y_{ijt} is the set of m country-pair specific variables and μ_{ijt} represents the error term. Whereas the set of country-pair specific variables comprises the distance, highway and internet-hosts indicators, the set of industry-specific variables contains all other explanatory variables which of course could also be described as country-pair specific, but data for these variables were drawn on industry level. The emerging panel data set covers 136 country pairs and three periods, leading to a total of 408 observations. In the first step, a pooled OLS regression technique will be used which, if indicated by test statistics, has to be extended by fixed and/or random effects estimations. But first of all, the problem of multicollinearity should be addressed. A test reveals a high correlation coefficient of 0,78 for the labour productivity ($CLDIFF_{ij}$) and labour cost difference ($LCDIFF_{ij}$) variables. From an economic perspective, this result is not surprising and one could argue that labour unit cost differences are the more suitable indicator. But for the issue at hand, this might be questionable, since labour productivities and thus labour unit costs depend largely on production technology and are, contrarily to labour costs, in large parts firm-specific. Therefore, it can be assumed that at least in the case where firms are searching for potential locations for affiliate companies rather labour costs than labour unit costs will be considered. Thus, the labour productiv-

ity variable shall initially be left out. The results of the pooled OLS regression on the basis of equation (1) are presented in Table 1.

Table 1:
OLS Estimation Results

Variable	Coefficient	Standardized (Beta-) Coefficient	t-statistic
Constant	1.0119**	n/a	2.186
EoS_{ij}	0.0358	0,0753	1.430
NoF_{ij}	0.0583***	0,1452***	3.074
$LCDIFF_{ij}$	0.0812***	0,2554***	4.659
$minWEBHOSTS_{ij}$	0.0868***	0,2283***	4.594
$DIST_{ij}$	-0.0818***	-0,1391***	-2.945
$HIGHWAYS_{ij}$	0.0743**	0,1213**	2.365
$HTRDIFF_{ij}$	-0.0468***	-0,1369***	-2.700

Significance levels: ***(1%), **(5%), *(10%). –R^2 = 0,21. – No. of Obs. = 408

Source: Own calculations

As can be seen from the results in Table 1, many of the explanatory variables are significant with the expected sign. If the labour cost difference variable ($LCDIFF_{ij}$) is replaced by the labour productivity variable ($CLDIFF_{ij}$) the results are quite similar, implying that both, differences in labor costs and/or labor productivities are essential.[3] But a problem of the simple OLS regression technique could be individual, in this case country-pair specific effects which would lead to biased estimates. To eliminate this shortcoming, fixed effects models are a suitable instrument, since this approach permits to consider unobserved heterogeneity of individuals. In the one-way fixed effects model, this heterogeneity is assumed to be constant over time for each individual. In the empirical analysis at hand, the pooled OLS model of equation (1) would change to a one-way fixed effects model of the following form:

$$PCSHARE_{ijt} = \alpha + \beta_n X_{ijt} + \gamma_m Y_{ijt} + \delta_{ij} + \mu_{ijt} \qquad (2)$$

As in equation (1), $PCSHARE_{ijt}$ stands for the share of parts and components trade in total trade of SITC groups 7 and 8 between countries i and j in period t. X_{ijt} is, as above, the set of n industry-specific variables and Y_{ijt} represents the set of m country-pair specific variables. δ_{ij} represents the fixed effects of each country pair i and j which are con-

3 Results might be obtained on request.

stant over time. Of course, in the fixed effects model due to multicollinearity problems the variables $DIST_{ij}$ and $HIGHWAYS_{ij}$ do not appear in the model equation. Whether a fixed effects model is superior to the pooled OLS regression can be derived from the likelihood ratio test. The test statistic (cross-section chi-square) of 407.26 underpins the superiority of the fixed effects model over the pooled OLS regression. Therefore, the estimation shall be rerun. The results of the fixed effects estimation are presented in Table 2:

Table 2:
One-way Fixed Effects Estimation Results

Variable	Coefficient	Standardized (Beta-) Coefficient	t-statistic
Constant	-1.0190	n/a	-0.414
EoS_{ij}	0.1987*	0,4177*	1.734
NoF_{ij}	0.1067	0,2656	1.001
$LCDIFF_{ij}$	-0,0283	-0,0890	-0,710
$minWEBHOSTS_{ij}$	0.0611**	0,1605**	2.558
$HTRDIFF_{ij}$	-0,0251	-0,0739	-0,659

Significance levels: ***(1%), **(5%), *(10%). – R^2 = 0,55. – No. of Obs. = 408

Source: Own calculations

With the fixed effects model, most of the formerly significant explanatory variables turn insignificant. According to the fixed effects estimation results, fragmentation of production is neither influenced by endowment, productivity and/or factor price differences nor by factors other than internet hosts influencing the costs of slicing up the value chain internationally. But in light of the poor results of the fixed effects estimation, another option shall be tested, namely the application of a random effects model.

Contrarily to the fixed effects approach, random effects models act on the assumption that the heterogeneity of observations is not based on individual fixed effecs, but is instead randomly distributed. In the random effects model presented in equation (3), v_{ij} represents the random effects, which should be normally distributed.

$$PCSHARE_{ijt} = \alpha + \beta_n X_{ijt} + \gamma_m Y_{ijt} + v_{ij} + \mu_{ijt} \quad (3)$$

The assumption that individual differences are now considered as random disturbances requires that the regressors and the v_{ij} are uncorrelated. To control for this assumption, the Hausman-Test is applied. The resulting chi-square test statistic with a value of 5.85 indicates that the individual effects seem to be randomly distributed and hence argues in favor of the random effects model. In the random effects model, the distance and high-

way variables are re-integrated again. The results of the random effects estimation are shown in Table 3.

Table 3:
Random Effects Estimation Results

Variable	Coefficient	Standardized (Beta-) Coefficient	t-statistic
Constant	0.9493	n/a	1.544
EoS_{ij}	0.0564*	0,1185*	1.752
NOF_{ij}	0.0542**	0,1348**	2.169
$LCDIFF_{ij}$	0.0566***	0,1780***	2,744
$minWEBHOSTS_{ij}$	0.0736***	0,1935***	3.955
$DIST_{ij}$	-0.0727**	-0,1236**	-2.059
$HIGHWAYS_{ij}$	0.1259***	0,2055***	3.103
$HTRDIFF_{ij}$	-0.0349*	-0,1021*	-1.720

Significance levels: ***(1%), **(5%), *(10%). – R^2 = 0,17. –No. of Obs. = 408

Source: Own calculations

According to Table 3, all explanatory variables are again significant with the expected sign. As the results of the statistically firm random effects model show, international fragmentation of production measured by the share of parts and components trade in total bilateral trade depends on firm specific factors as well as on infrastructural and cost determinants. As for the firm specific factors, firm sizes and economies of scale promote bilateral parts and components trade significantly. Although according to new trade theories economies of scale are supposed to foster trade in general, their influence on trade in intermediate goods is apparently higher than average. Therefore, as postulated by Jones and Kierzkowski (2001), greater levels of firms output encourage greater degrees of fragmentation due to strong increasing returns to scale in service link activities. Moreover, increasing numbers of firms in trading partner countries seem to foster intermediate goods trade and thus fragmentation of production. Like in the case of firm sizes, the number of firms' influence on parts and components trade is larger than on trade in final products. On first sight, this might appear a little bit astonishing since a growing number of firms in both trading partner countries would ceteris paribus diminish economies of scale. But the influence of the number of establishments on bilateral parts and components trade is quite manifold. First, with a growing number of firms a countries' potential either to offer intermediate products for foreign partners or to source components from abroad rises. Second, search costs for potential partners abroad diminish with increasing 'market thickness'. In this context, rising numbers of firms in trading partner countries, similarly to the final goods case, lead to an increasing supply

of differentiated intermediate goods and thus increase intra-industry trade not only in final products, but also in parts and components. Finally, agglomeration effects and network externalities come into force leading to decreasing unit costs of intermediate goods producers in core regions.

As far as factor prices and endowments are concerned, labor cost differences do influence bilateral trade in parts and components significantly in the expected positive way. But if the $LCDIFF_{ij}$ variable is replaced by the labor productivity variable, the latter is also highly significant, as was already the case in the simple OLS estimation. Thus, labor cost and factor endowment differences are crucial factors for explaining international fragmentation of production between countries. But interestingly, differences in research and development expenditures chosen as an indicator for diverging technological capabilities and/or labor force qualifications do apparently influence the establishment of international production networks in a negative way. This confirms the empirical artifact that lacking abilities of potential partner countries to adopt their production processes qualitatively to the needs of principal firms in highly developed countries limit the establishment of international production networks.

As far as service link costs are concerned, all variables are significant. A growing number of internet hosts (per ten-thousand inhabitants) reflecting the density of communication networks and communication and coordination costs between production sites increases the share of parts and components trade in total bilateral trade. As expected, distance between countries as an indicator for transportation costs seems to exert a larger influence on intermediate than on final goods trade. Additionally, international fragmentation of production is positively correlated with the quality of infrastructure measured by the share of highways in total distance between countries, supporting the hypothesis that not only transportation costs, but also times are a crucial factor for relocating parts of the production chain.

The standardized (beta-)coefficients in Table 3 show that labor cost differences (resp. endowment differences) do have a comparatively large influence on international fragmentation of production. But the influence of service link costs, especially coordination costs measured by the availability of communication infrastructure, as well as the quality of infrastructure and shipping times seem to exert an even larger influence on the share of parts and components in total trade than labor cost differences. Hence, although labor cost and/or endowment differences between countries undoubtedly triggered international fragmentation of production in the last decades, low service link costs are a necessary by-product. The influence of market thickness in trading partner countries as well as firm sizes is, albeit significant, of minor importance.

After all, a concluding remark on the estimation results has to be made with respect to the dependent variable. Since not the absolute level of parts and components trade, but its share in total trade in the SITC groups 7 and 8 was chosen as dependent variable, the significant influences of some of the explanatory variables become even more remark-

able. Of course, especially distances, the quality of infrastructure, firms sizes and economies of scale or communication networks between countries do influence trade in general in a positive way. But the empirical results confirm the hypothesis that their influence on parts and components trade is apparently by far larger than on trade in general. Put differently, the fact that the firm size variable is not highly significant does only mean that the influence of economies of scale on the international exchange of parts and components is not extraordinarily higher than on trade in final goods, although its influence on the absolute level of parts and components trade between countries would probably be highly significant. Contrarily, the impact of the endowment variables on total trade is unclear, since differences in endowments or factor prices should increase inter-industry, but reduce intra-industry trade. In contrast, their influence on parts and components trade is theoretically more clear-cut and could be confirmed empirically.

5 Conclusions

In the course of the last decades, international trade increased tremendously not only in absolute, but also in relative terms, i.e. in relation to world GDP. Additionally, the pattern of international trade changed, as the share of parts and components in total trade increased at the expense of final goods and amounted to at least 30 per cent in total exports of OECD countries. These high shares of intermediate goods in total trade are associated with international fragmentation of production which could be observed during the last decades as a consequence of further trade liberalization efforts and not least by the integration of Newly Industrializing and Post-Communist Economies into the international division of labor. Theoretically, factor price differences and service link costs are supposed to be the driving forces behind the phenomenon of disintegration of production.

Although in the European Union the shares of intermediate goods trade are comparatively high in trade between Western and Eastern European countries, the popular belief that Western European countries are net-importers and Eastern European countries are net-exporters of parts and components is not supported by empirical findings. Moreover, Belgium is the only Western European country with considerable comparative disadvantages in parts and components trade with Eastern Europe, whereas the United Kingdom, Ireland and the Netherlands even seem to have comparative advantages in intermediate goods trade with this country group. In contrast, Slovenia is the only Eastern European country with considerable comparative advantages in parts and components trade with the Western European countries, whereas Hungary, Slovakia and fractionally Poland show, against one's expectations, comparative disadvantages. Thus, for most countries parts and components trade seems to take place either in the form of back and forth transactions or, alternatively, the structure of intermediate goods trade results from vertical specialization of countries in parts and components production.

In the preceding analysis, a panel data set with bilateral trade in parts and components between 17 European countries as an indicator for international fragmentation of production was applied to identify the main determinants of the establishment of international production networks. The analysis revealed that the influence of factor price and/or endowment differences on shifting production to or sourcing components from foreign countries can not be neglected. But apparently, labor cost (resp. endowment) differences are only one out of many explanatory factors. Additionally, transportation costs and delivery times seem to influence international fragmentation of production significantly. Moreover, firm sizes, the number of establishments in trading partner countries and service link costs measured by the availability of telecommunication technologies affect the extent of bilateral trade in parts and components. Last but not least, differences in research and development expenditures and thus labor force qualification and production technologies alleviate delocalization of production. As far as the magnitude of the different explanatory factors on the share of intermediate goods in total bilateral trade is concerned, the influence of the quality of infrastructure and the density of communication networks is even larger than that of factor price and endowment differences. Thus, service link costs seem to be not least important than differences in production costs.

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